Study of Sources of Light in the Deep Ocean

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LONG-TERM GOALS

My research is based on a long-standing interest in understanding a range of low-level light phenomena and the development and application of techniques for their detection[1]. In particular the goal is to extend this experience to the ocean's optical environment.

OBJECTIVES

At present I am continuing a comprehensive study of the various sources of light in the ocean at depths greater than 1500 m including bioluminescence, ionizing radiation, and the light observed at deep sea hydrothermal vents. In particular I want to identify the physical processes by which light in the visible region of the spectrum is generated at the orifice and plume of "black smokers", found in the deep sea ridges. Although radiation at long wavelengths can be attributed to thermal effects at the observed temperatures (~300-400° C), the light observed in the spectral range, 450-650 nm, is an order of magnitude greater than can be accounted for by thermal radiation at these temperatures.

During the past year, I have become associated with the planning of experiments for project "NEPTUNE" where instrumentation is expected to include a range of optical devices related to geophysical processes on the Juan de Fuca Plate. (See Figure 1.)

APPROACH

In addition to independent library research and laboratory experiments in my Princeton University laboratory I am involved in collaborations with scientists at the Woods Hole Oceanographic Institution, where I participate in the planning of experiments to be conducted during dives of the SLVIN and participate in the analysis and interpretation of data obtained to date. The technique used for initial observations of light from vents was a non-focusing diode detector with very poor spectral resolution: OPUS (Optical Properties Underwater Sensor). In subsequent dives a greatly improved detector was used capable of simultaneous spatial and spectral recording: ALISS (Ambient Light Imaging and Spectral Sensing). In related experiments I collaborate with Dr. A.J. Walton of the Cavendish Laboratory, Cambridge, UK designed to test hypotheses related to vent light.

Also interactions continue with R. Lutz and P. Rona of the nearby Rutgers University Marine and Coastal Science Institute.

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An important development during the past year has been to expand collaborations to include planning for long-range observations in the north east Pacific.

WORK COMPLETED

In the past several years, a number of successful dives of the Alvin have been conducted using OPUS, and recently ALISS. The data from OPUS have been analyzed and served as the basis for planning and executing drives utilizing ALISS[2]. The data analysis from ALISS has been completed and reported[3,4]. During the summer of 2001 three dives by the ALVIN at the Mid-Atlantic Ridge were completed using ALISS and the data are now in hand for analysis. Several laboratory experiments and analyses related to light emission from deep-sea hydrothermal vents have been reported during the past year[5,6,7].

RESULTS

Analysis of the data obtained during dives of 1997 and 1998 has been completed and submitted for publication[4]. The final analysis confirms that light in the visible exceeds that accountable for by thermal radiation. Data have been obtained from 3 dives on the Mid-Atlantic Ridge during the summer of 2001 and analysis is underway. It has also been demonstrated that particles of minerals found in vent plumes emit light via vapor bubble luminescence[8]. Library research on sources of light in the deep ocean has resulted in a publication in the Reviews of Geophysics.

IMPACT/APPLICATIONS

The identification of light sources in the deep ocean has significance for science (bioluminescence, DUMAND type physics programs, military). The significance of hydrothermal vent studies has been well stated in “Seafloor Hydrothermal Systems”, AGU Geophysical Monograph 91 (1995) ed. S.E. Humphris, R.A. Zurenberg, N.S. Mullineau and R.E. Thourson as follows:

“Hydrothermal circulation at mid-ocean ridges is one of the fundamental processes controlling the transfer of energy and matter from the interior of the Earth to the lithosphere, hydrosphere, and biosphere. Hydrothermal interactions influence the composition of the oceanic crust and the chemistry of the oceans. In addition, hydrothermal vent fields support diverse and unique biological communities by means of microbial populations that link the transfer of the chemical energy of dissolved chemical species to the production of organic carbon.”

Light is an important aspect of the ecology of the deep ocean. Hydrothermal vents have received particular attention in recent years[8]. The deep sea may have served as a refuge for continuing life on the occasions of terrestrial catastrophies and the study of existing forms and their means of interacting (via light) provide important information on the history of terrestrial life.

TRANSITIONS

The results of deep sea studies, and particularly hydrothermal vents are of direct interest to programs concerned with the origin of life, extraterrestrial biology (NASA, SETI). The present studies of Europa, a moon of Jupiter, have suggested the possibility of some sort of “sea”, and if so vents? And if so life? Techniques for studying life on earth under extreme conditions will possibly provide means for extraterrestrial studies.

RELATED PROJECTS

Studies of “deep sea” bioluminescence and vent chimney structures are underway at the University of California, Santa Barbara[9,10,11] chemistry and phase separation of vent fluids at the University of New Hampshire[12] and chimney structures of black smokers at the Woods Hole Oceanographic Institution[13,14].

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